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	Responsible Engineer(s) David J. Thompson	Supersedes None
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Document Title Balloon Flight - Fabrication, Testing, and Operations - Final Report		

Gamma-ray Large Area Space Telescope

(GLAST)

Large Area Telescope (LAT)

Balloon Flight - Fabrication, Testing, and Operations

Final Report

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes	DCN #
1		Initial Release	

Acronyms

ACD - AntiCoincidence Detector
BFEM - Balloon Flight Engineering Model
BIU - Balloon Interface Unit
BTEM - Beam Test Engineering Model
CAL - Calorimeter
DAQ –Data Acquisition System
FOV – Field of View
GLAST – Gamma-ray Large Area Space Telescope
GRIS - Gamma Ray Imaging Spectrometer (gondola borrowed from this project)
IOC – Instrument Operations Center
LAT – Large Area Telescope
MIP – Minimum Ionizing Particle (see definition below)
PHA - Pulse height analysis
PI – Principal Investigator
SAS – Science Analysis Software
TKR - Tracker
XGT - External Gamma Target

Definitions

μsec, μs – Microsecond, 10^{-6} second
Background Rejection – The ability of the instrument to distinguish gamma rays from charged particles.
Backsplash – Secondary particles and photons originating from very high-energy gamma-ray showers in the calorimeter giving unwanted ACD signals.
cm – centimeter
Cosmic Ray - Ionized atomic particles originating from space and ranging from a single proton up to an iron nucleus and beyond.

Dead Time – Time during which the instrument does not sense and/or record gamma ray events during normal operations.
Demonstration – To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results.
eV – Electron Volt
Field of View – Integral of effective area over solid angle divided by peak effective area.
GeV – Giga Electron Volts. 10^9 eV
MeV – Million Electron Volts, 10^6 eV
Minimum Ionizing Particle – The mean signal from cosmic ray produced air shower muons normally incident on a scintillator tile. It corresponds to approximately 1.9 MeV per cm of scintillator.
nsec – Nanosecond, 10^{-9} second
ph – photons
s, sec – seconds
Simulation – To examine through model analysis or modeling techniques to verify conformance to specified requirements

APPLICABLE DOCUMENTS

Documents that are relevant to the development of the balloon flight include the following:

"GLAST Large Area Telescope Flight Investigation: An Astro-Particle Physics Partnership Exploring the High-Energy Universe", proposal to NASA, P. Michelson, PI, November, 1999.

"Report on the GLAST LAT Balloon Test Flight Objectives," July 12, 2000

GLAST-BFRD-1, "LAT Balloon Flight Requirements Document," August 8, 2000

"Balloon Flight Objectives and Constraints", June 10, 2000

"Balloon Flight Budget," September 11, 2000

"Balloon Power Systems and Packaging Concepts," Sept 14, 2000

"Draft Mass and Power Budget", Aug 10, 2000

"GLAST Balloon Flight Engineering Model - Plan for Balloon Flight", BFEM-00001-P1, 10/6/00

"GLAST Balloon Flight - Results Needed to Meet Objectives and How to Obtain Them", 10/30/00

"Risk Assessment/Mitigation for the GLAST Balloon Flight ," 11/13/00

"Project Plan for Thermal Modeling and Analysis of the NASA/GSFC/LHEA GLAST Science Payload", 11/16/00

"GLAST Balloon Flight 2000", 12/6/00

"GLAST Offline Software Tasks and Schedule," 12/14/00

"Balloon Flight WBS and Schedule," 12/26/00

CONTENTS

1. Introduction

In its response to the NASA Announcement of Opportunity, the Large Area Telescope (LAT) team proposed a suborbital test flight of some sample hardware, specifically a balloon flight of a modified version of the single tower used in the 1999-2000 beam test (the Beam Test Engineering Model - BTEM). In the Summer of 2000, a balloon flight team was organized with Dave Thompson, Gary Godfrey and Scott Williams as leaders. During the next 12 months, the balloon flight team built, tested, and successfully flew the Balloon Flight Engineering Model (BFEM). Preliminary results from this balloon flight are available, and data analysis is continuing. This report describes the process of planning, building, testing, flying, and analyzing data from the BFEM, along with a brief summary of some lessons learned that may be applicable to the flight unit development.

2. Rationale/Goals

The original rationale for a balloon flight was stated in the NASA Announcement of Opportunity:

> **"The LAT proposer must also demonstrate by a balloon flight of a representative model of the flight instrument or by some other effective means the ability of the proposed instrument to reject adequately the harsh background of a realistic space environment. … A software simulation is not deemed adequate for this purpose."**

One of the first aspects of planning the balloon flight was to identify specific goals that were practical to achieve with limited resources (time, money, and people), using the previously-tested Beam Test Engineering Model (BTEM) as a starting point. Considerable discussion led to the following (**GLAST Balloon Flight Engineering Model - Plan for Balloon Flight)**:

> The purpose of the balloon test flight is to expose the prototype tower (BFEM) closest practical to the flight version of GLAST-LAT to a charged particle environment similar to the space and accomplish the following objectives:
> a) Validate the basic LAT design at the single tower level.
> b) Show ability to take data in the high isotropic background flux of energetic particles in the balloon environment.
> c) Recording all or partial particle incidences in an unbiased way that can be used as a background event data base.
> d) Find an efficient data analysis chain that meet the requirement for the future Instrument Operation Center of GLAST.

It was quickly realized that a single tower on a short balloon flight would not be able to detect any astrophysical sources; for this reason, the emphasis was on secondary gamma-ray production that would provide a measurable source flux to be detected against the large background of charged particle cosmic rays. Two such sources were identified: the secondary atmospheric gamma radiation, which has properties that have been measured in previous balloon flights of gamma-ray detectors; and an active target in which cosmic ray protons could interact to produce secondary gamma rays. Calculations indicated that both these sources would be measurable in a balloon flight of a few hours duration.

3. Fabrication/Test

Once a decision was made to build and fly a balloon test instrument, the work went through a series of stages leading up to launch readiness. These are described below.

3.1 Planning

In converting the general concept of a balloon flight into a plan, the first challenge was to identify constraints, requirements, and available resources.

The principal planning constraints were: (1) limited funding and manpower (any effort on the balloon instrument was drawn away from the flight unit development); (2) limited flight opportunities (the National Scientific Balloon Facility conducts short flights like these principally from their base in Palestine, Texas, during the Summer months); and (3) the need to complete the balloon flight before the Preliminary Design/Baseline Review (in order to take advantage of the results of the flight).

The principal requirements for a balloon flight were: (1) a set of detectors functionally equivalent (not necessarily identical) to a GLAST tower; (2) a readout, command, telemetry, and data storage system that could operate remotely (i.e. without physical contact to a ground station); (3) a pressure vessel to house the instrument (test electronics are not designed to operate in a vacuum); and (4) a supporting gondola to hold the instrument during flight.

In light of the time and cost constraints, the only practical way to carry out this balloon program was to re-use as much existing hardware and software as possible. Fortunately, we found available resources for three out of the four major needs:

(1) Detectors: The existing Beam Test Engineering model included a set of trackers, a calorimeter, and an anticoincidence detector - Fig. 1. Although not identical to the flight design detectors, all three subsystems use the same basic techniques that will be applied to the flight unit.

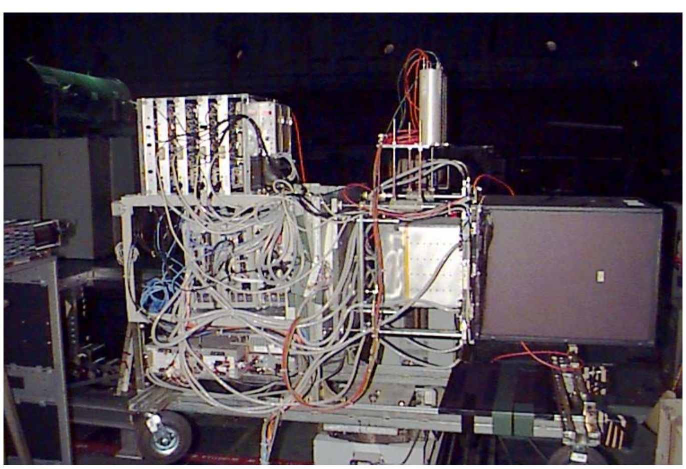


Fig. 1 - The Beam Test Engineering Model (BTEM), a prototype GLAST/LAT tower. The black box to the right is the anticoincidence detector (ACD), which surrounds the tracker (TKR). The aluminum-covered block in the middle is the calorimeter (CAL). Readout electronics were housed in the crates to the left.

(2) Pressure Vessel: An existing mechanical structure/pressure vessel of appropriate dimensions was found at Goddard Space Flight Center - Fig. 2. This vessel had been flown twice on balloons with a heavier instrument than the BFEM (Bob Hartman's Advanced Compton Telescope), therefore offering some confidence that it would work for the GLAST flight.

Fig. 2 - Pressure vessel, support bulkhead, and work stand found at Goddard to house the BFEM. The white insulation is part of the existing thermal control.

(3) Gondola: A gondola previously used by the Gamma-Ray Imaging Spectrometer (GRIS) balloon experiment was loaned to the GLAST team by Jack Tueller and colleagues - Figure 3. GRIS was significantly heavier than the BFEM, offering confidence that the gondola would meet all safety requirements and carry the BFEM successfully.

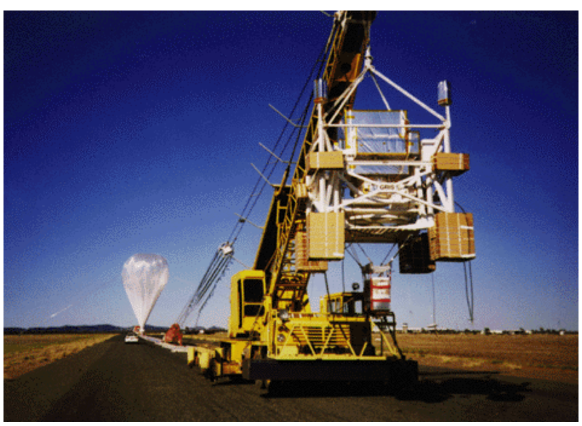


Fig. 3 - The GRIS instrument, housed in the gondola that was borrowed for the BFEM flight, was flown successfully on balloons many times. This flight was one from Alice Springs, Australia.

The fourth part of the requirements - readout, commanding, data storage, and telemetry hardware and software - required the largest investment in development. The Data Acquisition System (DAQ) that had been used for the BTEM was not designed for the high rates expected in the balloon flight, and none of the commanding and data handling for the beam test needed to operate without a physical link to the detector. For these reasons, the largest part of the resources were devoted to upgrading the DAQ and producing the required hardware and software for the data and command handling.

Once the elements of the balloon program were identified, an overall plan was developed, with responsibilities divided among many of the GLAST LAT institutions. A sketch of the hardware portion of that plan is shown in Figure 4.

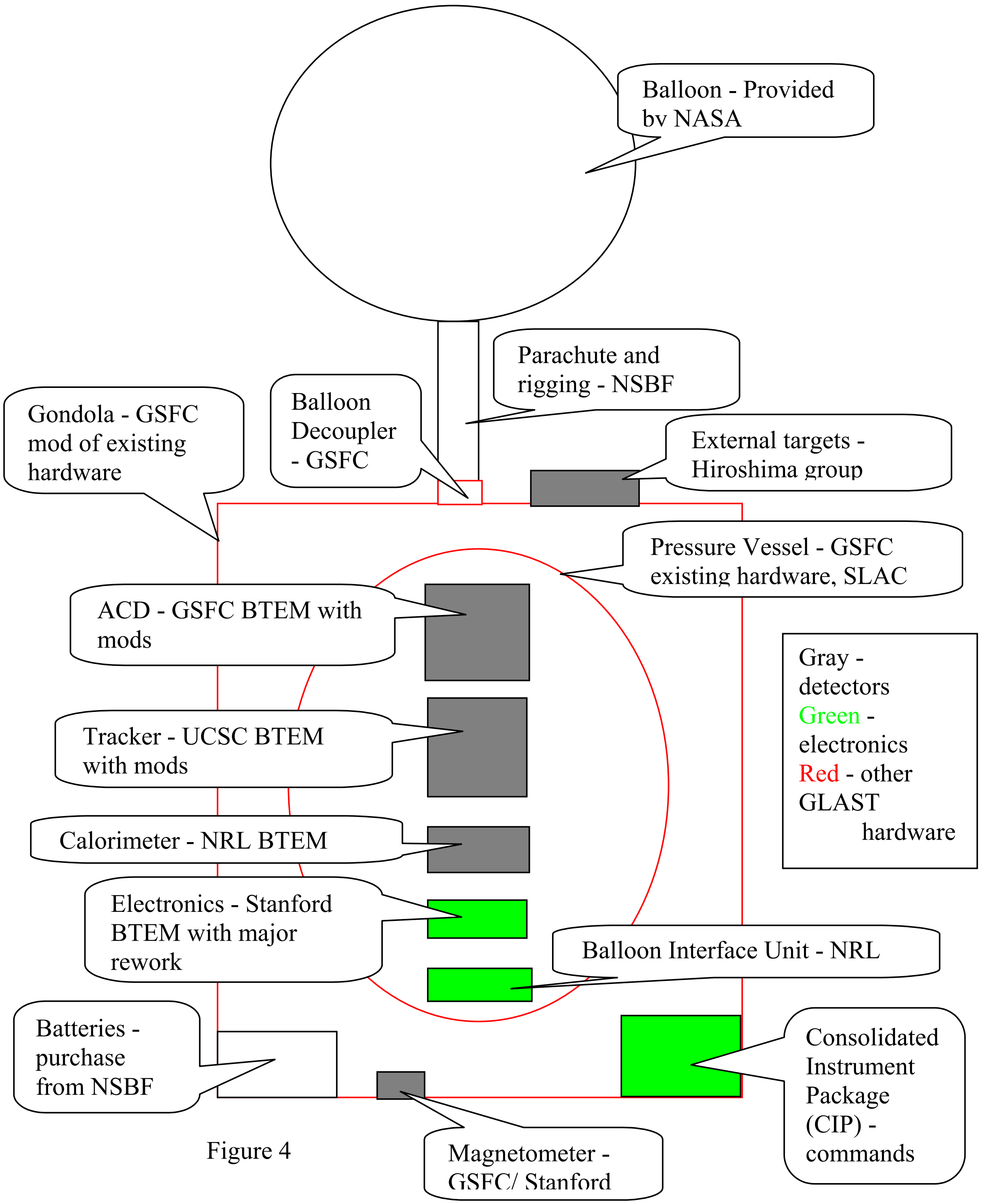


Figure 4

Figure 5 is a sketch of the plan for the command and data flow, indicating responsibilities of the various groups for electronics and software.

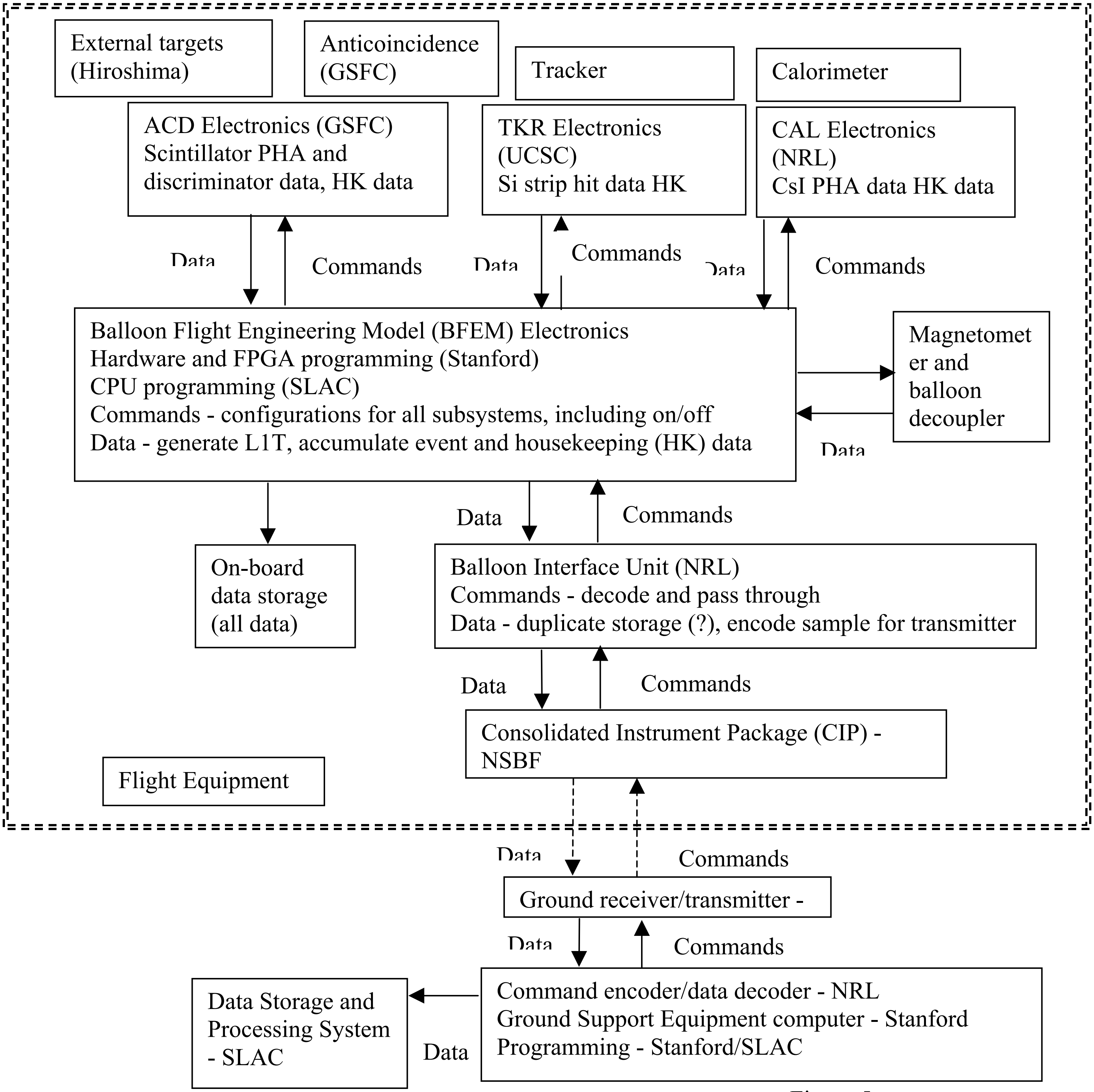


Figure 5

As can be seen from these two figures, the balloon program includes simplified versions of all the elements of the full GLAST program. The instrument and readout electronics are a scaled-down version of the LAT. The BIU, power, command, and telemetry systems serve functions that will be provided by the spacecraft. The ground system works in a way analogous to the Instrument Operations Center for the flight unit.

Due to the constraint of completing the balloon flight before the Preliminary Design/Baseline review (scheduled for August, 2001, at the time the balloon program started), the top level schedule called for:

Instrument assembly and test at SLAC	November, 2000 - February, 2001
Payload assembly and test at Goddard	March, 2001 - May, 2001
Balloon operations in Texas	June, 2001

Working from the outline, Scott Williams produced a full Work Breakdown Structure, including schedule and budget, for all the work needed to accomplish this work. This planning effort for the balloon program was incorporated into the PMCS system.

3.2 Instrument Assembly/Test

The myriad details of assembly of the BFEM are beyond the scope of this report. Most importantly, at the beginning of the balloon program the BTEM no longer existed in the form shown in Fig. 1. The BTEM had been disassembled and the subsystems returned to their home institutions for testing. In addition, the BFEM had to be mounted in the pressure vessel rather than on the table used for the BTEM, and some subsystem modifications were necessary: some tracker layers from the BTEM were needed for testing, and the calorimeter group felt it prudent to add "flying buttress" supports to the outside of the calorimeter (because a balloon flight often involves shock loads of 10 g or more when the parachute opens on descent and again when the payload hits the ground). The BFEM assembly therefore had to start with a reassembly of the BTEM detectors and then move on from there. Some important steps in the instrument assembly and test process (led by Gary Godfrey) were:

Pressure vessel test - The pressure vessel was filled to 1.5 atmosphere differential pressure (compared to the ~1.0 atmosphere differential seen at balloon float altitude), and the leak rate was confirmed to be slow enough that there would be no significant loss of pressure during a one day flight.

Detector assembly - The CAL, TKR, and ACD were mounted and solidly attached to the bulkhead structure - Figure 6.

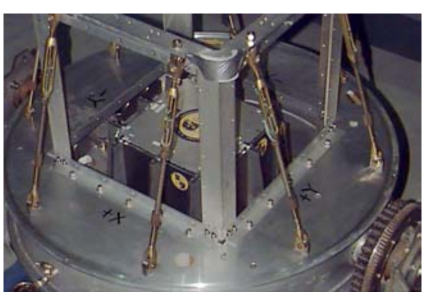
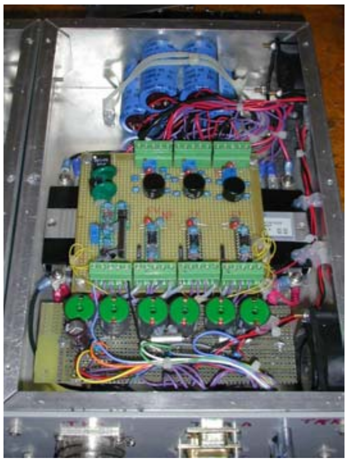


Figure 6 - Sequence showing the mounting of the Calorimeter, Tracker, and ACD.

Power supplies (the batteries supply 28 V; therefore all other voltages must be converted from this one), a set of hard disks for on-board data storage, and supporting electronics were built and assembled into the BFEM - Fig. 7



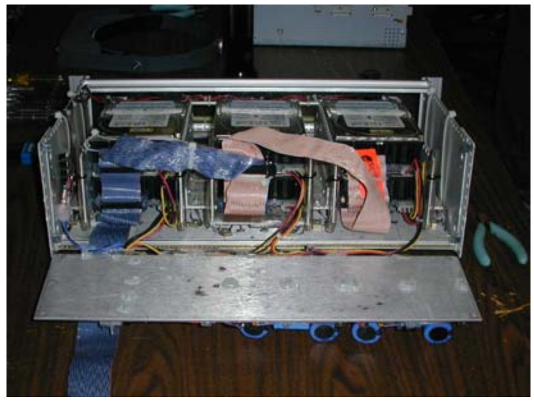


Figure 7 - Left: power supply box for the TKR. Right: the six 70 Gbyte disks for on-board data storage.

The BTEM DAQ underwent a major upgrade (primary work by James Wallace and Dave Lauben) to assure that data from the subsystems were synchronized and that high data rates could be accommodated.

Flight commanding and data handling software were written. The BFEM system was sufficiently different from the BTEM that this work represented a completely new program. The data handling software, including writing all data to on-board disks and a sample of the data to the Balloon Interface Unit (BIU) for telemetry, was the work of J. J. Russell, who also provided the most accurate assessment of the schedule. Tony Waite, with help from Dan Wood and Bob Schaefer, led the commanding software development. Balloon commanding is done with 16 bit words at a very slow rate (1 Hz maximum); therefore the commanding had to be extremely compact.

A set of eXternal Gamma Targets (XGT), consisting of blocks of plastic scintillator attached to photomultiplier tubes, were mounted above the ACD. The signals from these targets could be used to identify interacting protons that might produce gamma rays. They could, therefore, provide an easily-modeled signal with an absolute flux and position to use as an in-flight calibration. This work was led by Tune Kamae and Tsunefumi Mizuno, with help from students.

The instrument was tested after assembly (Figure 8) and was shown to be able to take useable data, as displayed on Electrical Ground Support Equipment (EGSE) developed by Dave Lauben - Figure 9.

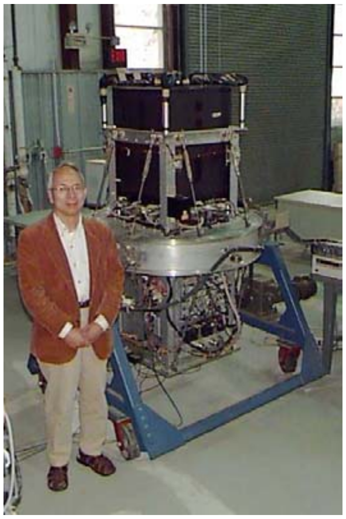


Figure 8 - The assembled BFEM.

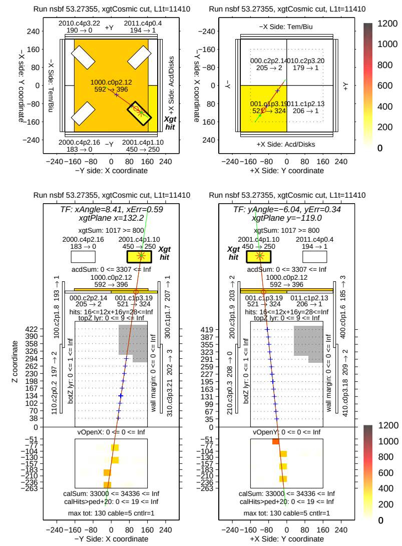


Figure 9 - Real-time event display of a muon track penetrating the BFEM. Colors represent energy deposit. The track can be seen in the XGT, the ACD, the TKR, and the CAL.

Preliminary thermal testing indicated that the thermal model developed under contract by New Mexico State University required some modification. A radiator/cooler was built to keep the instrument cool while closed and operating.

On May 24, a pre-ship review was held. The BFEM was shown to be able to operate through a set of nominal runs and record data at high rate. The review team was satisfied that the BFEM was ready to ship to Goddard.

3.3 Payload Assembly/Test

Work at Goddard concentrated on making the working instrument ready for the balloon flight. Some of the important steps are described below.

Before the BFEM arrived at Goddard, the GRIS gondola was refurbished and adapters were made to match the mounting of the BFEM - Figure 10

Figure 10 - The GRIS gondola with the adapter to mount the BFEM.

The Balloon Interface Unit (BIU) work (led by Michael Lovellette) was completed, along with the external electronics boxes for interfaces, commanding, and battery power - Figure 11.

Figure 11 - The external power/electronics panel for the BFEM. These boxes include the batteries, the relays for powering subsystems, and the telemetry interface for commanding.

The command software was improved to produce a graphical interface for each command, with confirmation required for all critical commands.

The on-board software was upgraded with a number of improvements. The DAQ and BIU configuration files were stored on board in a flash memory, making the BFEM autonomous of any physical link to the ground station (critical work by Dan Wood).

Additional thermal testing for longer periods revealed some additional thermal issues that required modifications of the disk crate and the air flow within the pressure vessel. At the recommendation of experienced balloon scientists at Goddard, an evaporative cooler with a water reservoir was added as a precaution. With these modifications, the thermal environment within the BFEM appeared adequate for a 10 hour flight.

Several leak tests on the pressure vessel were carried out. Due principally to a concern about overpressuring the on-board disks, the leak test was done with a differential pressure of 1.5 - 2 psi. A technique for sealing the vessel was developed that reduced the leak rate below measurable levels on a 12 hour time scale.

Numerous housekeeping and auxiliary science parameters were added to the data, including an internal pressure sensor, many temperature sensors, a magnetometer, and an external pressure sensor.

Several data displays were added or improved, to allow quicker monitoring of essential rate, voltage, and temperature parameters (mostly work by Dave Lauben and Bob Schaefer).

All essential test and operating procedures were documented.

A pre-ship review was held on July 16, 2001. The review concentrated on the question, "What could go wrong?" Risks studied included possible problems with detectors, data storage, thermal, leak, the balloon, electromagnetic interference, human error, and software. The review team expressed some concern about the thermal control but otherwise concluded that the risks were small enough to warrant shipment to the National Scientific Balloon Facility (NSBF).

4. Operations

As balloon campaigns go, the BFEM operations at the NSBF were remarkably smooth. The instrument was assembled into the gondola, batteries were wired, the interfaces with the NSBF equipment were checked and verified, additional insulation was added, crush pads were mounted, and plans for launch were all completed in less than one week. Figure 12 shows the full instrument flight configuration and many of the flight team members.

Figure 12 - Left: the fully-assembled BFEM during a pre-flight test (hanging from the NSBF "Tiny Tim" launch vehicle. Right: many members of the BFEM flight team in front of the instrument.

On Friday, August 3, 2001, the BFEM team held a flight-readiness review with the NSBF staff. Based on the documentation supplied (such as pressure test results and load test results) plus the testing that had been done on-site by the NSBF staff, the GLAST BFEM was approved for launch on a 29 million cubic foot balloon.

On Saturday, August 4, 2001, just before noon, after a five hour weather delay (high winds a few hundred feet above the ground), NSBF flight 1579-P, carrying the GLAST BFEM was launched - Figure 13 shows several photos from the launch sequence.

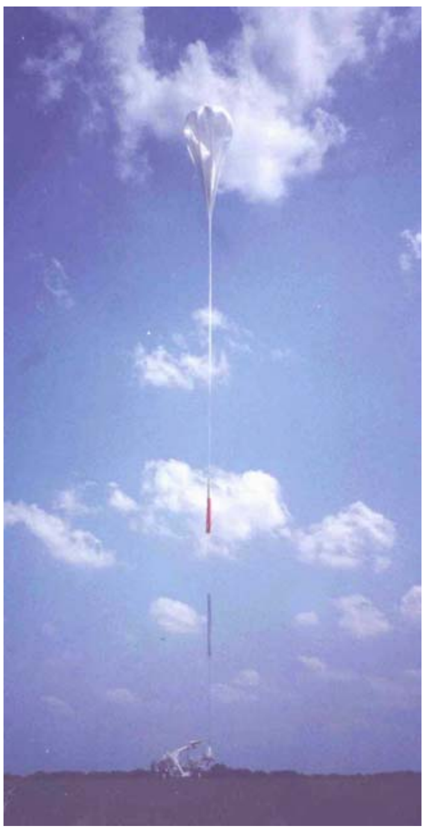


Figure 13 - Photos from the BFEM launch. Upper left: at dawn, the BFEM suspended from the launch vehicle. Upper right: filling of the balloon from the helium trucks. Left: the release of the BFEM from the launch vehicle (total height of the balloon at this point is ~ 240 m). The recovery parachute is the orange segment below the balloon.

The balloon carried the BFEM to an altitude of 38 km in a little over two hours. At an altitude of about 5 km, the readout showed that the pressure vessel began to leak. This leak continued until the internal pressure reached 2 psi, at which point the leak stopped. Despite concerns about losing the electronics, all systems continued to operate well except one - the on-board disks began showing errors at an altitude of about 20 km, and the flight team decided to turn off all the disks in the hope of recovering the data already recorded. The telemetry continued to run at 200 kbits/s, and a random sample of good data was collected throughout the flight.

The winds at float altitude carried the balloon rapidly west. After three hours at float, the BFEM reached the limit of telemetry from NSBF, over San Angelo, Texas, at which point the NSBF rules require that the flight be terminated. All BFEM systems were turned off, and the destruct command was sent to the balloon, bringing the payload down on the parachute. Both NSBF and BFEM recorders indicated a fairly violent shock (~20 g) when the parachute opened. Because the descent was too rapid to allow the repressurization of the BFEM vessel, it landed under a partial vacuum, and one of the domes collapsed (not designed to withstand a one atmosphere pressure differential from without). The payload was recovered and returned to Palestine, packed up and then shipped back to Goddard, where it has been disassembled so that the individual subsystems can be used for further testing.

5. Preliminary Results

The most important first result from the flight of the GLAST BFEM is that the instrument worked. All the detectors, plus the data acquisition system and the balloon interface unit, performed admirably throughout the flight. Over 100,000 triggers (using a simple level one trigger of three consecutive x-y tracker planes in a row registering a signal) were recorded from the telemetry at float altitude, and a comparable number were seen during the ascent portion of the flight. By itself, this data set meets three of the four objectives set forth for the flight (section 2):

a) Validate the basic LAT design at the single tower level.

b) Show ability to take data in the high isotropic background flux of energetic particles in the balloon environment.

c) Recording all or partial particle incidences in an unbiased way that can be used as a background event data base.

A second important result is that the trigger rate remained at a modest level throughout the flight - Figure 14 (thanks to Kamae, Giebels, Mizuno, and Lauben for compiling some early results).

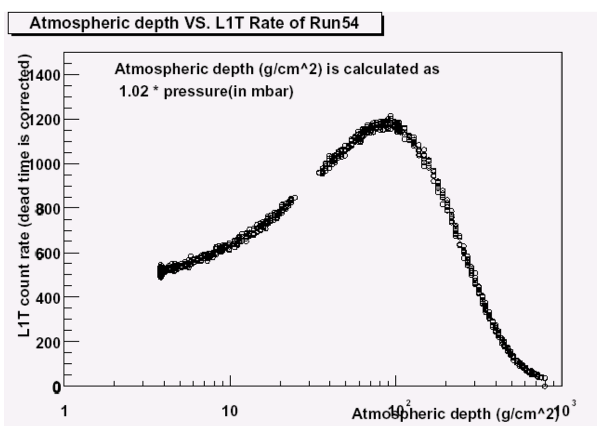


Figure 14 - the BFEM trigger rate as a function of atmospheric depth (often called a "growth curve"). Sea level has a depth of about 1000 g/cm^2, and the float altitude was at a depth of 3.8 g/cm^2.

Even through the Pfotzer maximum (the region of the atmosphere where the flux of secondary cosmic rays is largest), the trigger rate of 1.2 KHz remained well below the BFEM capability of 6 KHz. The 500 Hz trigger rate at float altitude is significantly less than some estimates, which ranged as high as 1.5 KHz for the BFEM.

The trigger rate as a function of depth is dominated by charged particles (secondary cosmic rays). The gamma rays represent only a small fraction of the total. The expected gamma-ray growth curve has a dramatically different shape, as can be seen by comparing Figure 14 with Figure 15. Noting that Figure 14 has a linear rate scale while Figure 15 has a logarithmic scale, it is clear that the gamma-ray rate increases with larger depth at a much faster rate than seen for the BFEM triggers. This comparison provides a straightforward test to verify the fourth goal of the balloon flight, i.e. data analysis and background rejection. Once the gamma rays are extracted from the BFEM data, they should also show the strong depth dependence, unlike the majority of the triggers. This work is part of the ongoing data analysis effort.

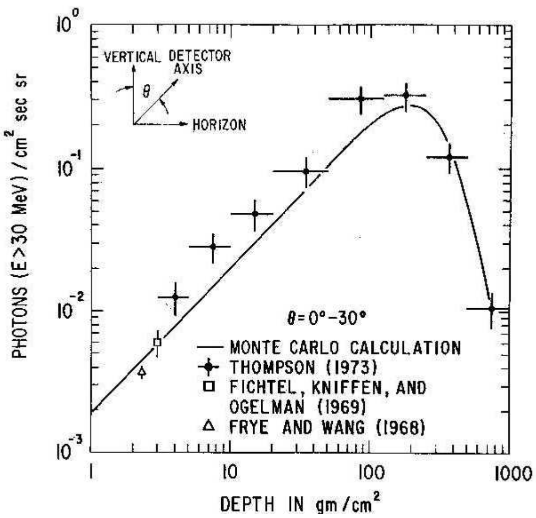


Figure 15 - The gamma-ray flux as a function of atmospheric depth, from a previous balloon instrument. At the Pfotzer maximum, the gamma-ray flux is ~60 times the rate at float altitude, in contrast to the factor of ~2 seen in the trigger rate for the BFEM (which is overwhelmingly dominated by charged particles).

The event data clearly included a variety of event classes in addition to the straight charged particle tracks similar to the one shown in Figure 9. Here are two examples of events seen in the flight data - Figure 16.

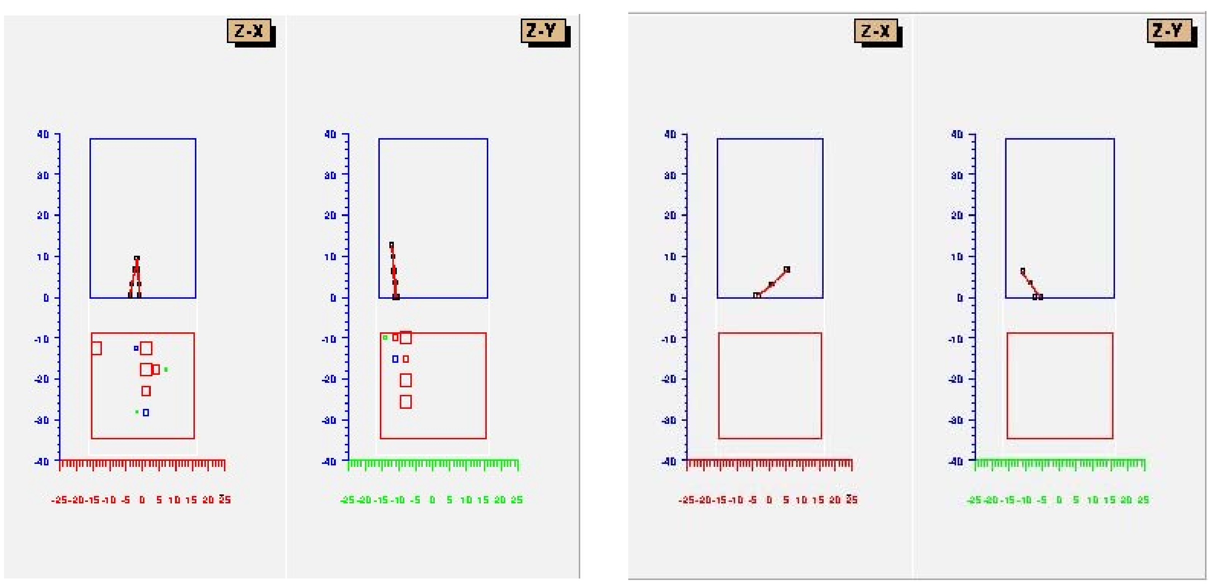


Figure 16: Events recorded during the balloon flight. Left: a probable gamma-ray pair production event. Right: a short single track that may or may not be a gamma-ray pair. The lines are the fitted track reconstruction, based on the tracker data only.

The event classes are largely familiar from beam tests and from previous gamma-ray telescopes like EGRET.

Some of these balloon flight preliminary results are more problematic. A comparison with the preliminary version of the GEANT4 simulation of the BFEM at float altitude showed that the predicted trigger rate is about half of that observed. Further, the fraction of events with no measurable energy deposit in ACD tiles ("neutrals") was predicted by the simulation to be less than 3%, but in flight was greater than 8%. Analysis is continuing, with an indication that the low-energy electron flux assumed for the model needs to be updated.

Continuing this analysis will be important to determine (by comparison with simulations) how much of the excess trigger rate and excess "neutrals" rate is due to the details of the BFEM itself, how much due to strictly-atmospheric effects (such as secondaries), and how much (if any) requires updates to the model being used for the primary LAT simulations.

The final step in meeting the balloon flight goals - demonstrating data analysis that adequately rejects the background - is still in progress. The flight data have been processed into a ROOT format and run through a track reconstruction program (RECON) based on work done for the beam test (see Figure 16). A set of data selections derived from those used for the AO response simulations plus some ideas from EGRET analysis produced candidate events that appear to be largely consistent with gamma-ray pair-production events. It is important to recognize that these are preliminary and not final results, however. Although examination of the event data strongly suggests that background rejection can be done, the careful subsystem calibrations and event analysis software to carry out this processing remain under development at the end of the operations phase of the balloon program.

6. Conclusions and Some Lessons Learned

The basic goals of the balloon flight were either achieved or are achievable with a well-defined analysis path. The BFEM successfully collected data using a simple three-in-a-row trigger at a rate that causes little concern when extrapolated to the full flight unit LAT. The trigger rate is dominated by charged particles, as expected. Gamma-ray pair events were seen. There seems little doubt that gamma-ray data can be extracted from the triggers and that the background can be rejected at an acceptable level.

In addition to providing a basic validation of the LAT design, the balloon flight offered a first opportunity for the LAT team to deal with many of the issues involved in a flight program. A number of "lessons learned" may be drawn from these experiences. Some of these lessons are fairly obvious; some may be somewhat controversial. The balloon flight team offers them as suggestions in hopes that our experiences, good and bad, might make the flight unit development slightly easier.

Lesson 1 - Test It Like You Fly It (Michael Lovellette's mantra). The single real failure in the balloon flight was the leak that developed in the pressure vessel. The pressure vessel had been tested to the flight-level differential pressure at SLAC, but after this test a number of penetrations of the vessel were added, all the detectors and support electronics were added, and the main o-ring seals were known to require careful seating. Once in the flight configuration, we chose not to repeat the full pressure test out of concern for overpressuring the on-board disks, instead replacing the full test with a lower-pressure leak test. Somewhat ironically, the one subsystem that failed because of the leak was the on-board disk storage. Beware of letting the schedule pressure short-change the testing. (Scott Williams' corollary) If we had taken more time for testing, we could have found a workaround for the disk drive concern.

Lesson 2 - Push for Autonomous Operation (Dan Wood emphasized this). On the ground, there is always the temptation to use a high-speed communications link for testing, but in flight there is no such link. Dan was insistent that we were not really operational until we did everything by remote command, relying on the stored configurations rather than software uplinks. As a result of doing testing in this mode as much as possible, the commanding during the flight went relatively smoothly.

Lesson 3 - The Simulation is Only as Good as the Input (Tune Kamae and Tsunefumi Mizuno recognized this). When the GEANT4 simulation underestimated the trigger rate and the fraction of events with no ACD signal (by factors too large to attribute to minor bugs in the program), the input assumptions became suspect. Especially at balloon altitudes, not all the components of the charges particle radiation are well-measured. We should be able to reverse-engineer the input from the BFEM data, because we have a sample of data at an essentially fixed geomagnetic location. It will not be so easy in the satellite, where the orbital changes add another dimension.

Lesson 4 - Teamwork is Important (Dave Thompson's favorite). The attitude on the balloon flight team was always goal-oriented. The most important question was, "What do we need to do to make this flight happen?" rather than, "Wasn't that someone else's job?" There were ample opportunities for "turf battles" in areas where subsystems had interfaces, but by and large the emphasis was always on solving the problem no matter whose work was involved.

The fabrication, testing, and operations phase of the balloon program is now complete, along with preliminary data analysis. Continued data analysis will explore the simulation/data comparison, the extraction of useful gamma rays, the rejection of background, and comparison with previous atmospheric gamma-ray data. Ongoing balloon data analysis efforts can be followed at these Web sites:

http://www-glast.slac.stanford.edu/LAT/balloon/

http://www-glast.slac.stanford.edu/LAT/balloon/meetings/

http://lheawww.gsfc.nasa.gov/users/djt/ANALYSIS/

7. Appendix

GLAST BALLOON FLIGHT ENGINEERING MODEL (BFEM) FLIGHT TEAM

NAME	AFFILIATION	ROLE
Chekhtman, Alexander	NRL	Analysis Software
Ampe, Jim	NRL/Praxis	Electrical Engineer
Baciak, Janet	NRL/SEI	Elec. Tech.
Broder, John	SLAC	Mech. Tech.
Buck, Darrin	GSFC/Swales	Elec. Tech.
Bumala, Bob	Stanford	Electrical Engineer
Clifford, Greg	NRL/SEI	Elec. Engineer
Daniels, Bill	GSFC	Elec. Tech.
Do Couto e Silva, Eduardo	SLAC	Analysis Software
Dubois, Richard	SLAC	Analysis Software
Escalera, Justino	SLAC	Elec. Tech.
Ferro, Deneen	GSFC/Swales	Elec. Tech.
Fewtrell, Ganwise	NRL/Praxis	GSE Software
Flath, Daniel	SLAC	Analysis Software
Godfrey, Gary	SLAC	Scientist - Co-PI
Grove, Eric	NRL	Scientist (CAL)
Handa, Takanobu	SLAC	Analysis Software
Johnson, Neil	NRL	Scientist (Calorimeter)
Kamae, Tsuneyoshi	SLAC	Scientist
Kavelaars, Alicia	SLAC	Analysis Software
Kelly, Heather	GSFC/EITI	Analysis Software
Kotani, Taro	GSFC/NRC	Analysis Software
Kroeger, Wilko	Santa Cruz	Scientist (Tracker)
Lauben, Dave	Stanford	Scientist (EGSE)
Lindner, Thomas	SLAC	Analysis Software
Lovellette, Michael	NRL	Scientist (BIU)
Lumb, Nick	Pisa	Analysis Software
Mizuno, Tsunefumi	Hiroshima	Scientist (XGT)
Mizushima, Hirofumi	Hiroshima	Student
Moiseev, Alex	GSFC/USRA	Scientist (ACD)
Nolan, Pat	Stanford	Scientist (EGSE)
Ogata, Sei	Hiroshima	Student
Phlips, Bernard	NRL	Scientist (Calorimeter)
Righter, Don	GSFC/Swales	Mech. Design.
Rochester, Leon	SLAC	Analysis Software
Roterman, Michael	SLAC/KTH	Student
Russell, J.J.	SLAC	Flight Software
Sadrozinski, Hartmut	Santa Cruz	Scientist (Tracker)
San Sebastian, Frank	GSFC/Swales	Mech. Design.
Sandora, Patty	NRL	Tech.

Schaefer, Bob	GSFC/EITI	Software
Spandra, Gloria	Pisa	Analysis Software
Tait, Bob	NRL/Praxis	Elec. Tech.
Thompson, Dave	GSFC	Scientist - PI
Usher, Tracy	SLAC	Analysis Software
Waite, Anthony	SLAC	Flight Software
Wallace, James	Stanford	TEM hardware
Williams, Scott	Stanford	Scientist - Co-PI
Wood, Dan	NRL/Praxis	Flight Software
Young, Karl	SLAC	Analysis Software